

Chapter

Defining Space Mission Architects for the Smaller Missions

Session A -Organization & Management

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Abstract: The definition of the Space Mission Architect (SMA) must be clear in both technical and human terms if we expect to train and/or to find the people needed to architect the numbers of smaller missions expected in the future. The SMA must deal with abstractions and political concerns on the one hand and rigid budgets and technology considerations on the other. Traditional scientists, engineers, and managers often do not like to deal with things that they can not get their hands on. The goal of sustaining a cadre of highly qualified professionals demands that we transcend traditional mind set patterns. A clear definition of a SMA's role is imperative. That role can be stated in terms of 1) the essential products, services, and deliverables that the SMA is expected to provide and 2) the constraints and the diversity of organizations that the SMA must satisfy. A refinement of that role statement can then be obtained by examining the skills, tools, techniques, and resources that the SMA uses to meet these mission needs.

Context of the Problem:

The Jet Propulsion Laboratory (JPL) is currently responding to the National Aeronautics and Space Administration (NASA) challenge for improvement in many ways. One response includes the development of new Centers of Excellence. The development of the Center for Space Mission Architecture and Design (CSMAD) is a critical step towards the challenge for faster, better, cheaper and smaller missions of the future. CSMAD is one of six Centers of Excellence at JPL, that are each chartered to foster world-class excellence in a particular technical area of strategic importance to JPL and NASA. The objective of CSMAD is to make JPL the clear leader in mission and system level

(architectural) conception, design, and implementation for Space Science and Earth Science missions. Dr. Stephen Wall, who spoke earlier in this session is the Manager of CSMAD.

Historical Methods and Changes:

JPL has historically tackled large problems with large projects. The method that evolved has relied upon the diversity and depth of a JPL staff including large teams of many kinds of experts. That method has proven successful for numerous and diverse missions. However, until recently, size and complexity grew with each new project.

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"If the current trends prevail, hardware will be too costly to manufacture or purchase; but there will be a thriving market for the sale of instruction books on how to use it." Augustine's Law Number XXXV [Augustine, 1983, p. 186].

When only a few SMA job openings occurred per decade with thousands of specialists to draw upon, the large project method could forgive a vague definition or even no definition of the SMA. We no longer have that luxury.

The smaller teams planned for future smaller missions must be able to efficiently infuse the best mission and system technology and practices into their methods. These smaller teams must recruit and keep Space Mission Architects with generalist outlooks and with the ability to wear many hats. JPL expects to have between three and ten new SMA openings per year for the next two decades.

A Clear Definition is Necessary:

The definition of the SMA must be clear in both technical and human terms if we expect to train and/or to find these people, and if we expect to keep them. Ever reaching science objectives and the national research goals have selected only outstanding members of the space science community. The technical requirements for a successfully executed space mission are formidable and only highly skilled engineers are selected and trained to serve on space mission development. The management requirements for a space mission project are equally daunting.

Traditional scientist, engineers, and managers often do not like to deal with those things that they can not get their hands on. In fact they are trained to actively avoid those things and experience has reinforced that training.

The SMA must control exactly those invisible intangibles that the traditional scientists, engineers, and managers would like to avoid. The SMA must deal with vague abstractions and political concerns on the one hand and rigid budgets and technology considerations on the other. The SMA must be the "honest broker" interface between the customers, managers, scientists, engineers, designers, builders, testers, and operators of the space mission system. Sustaining a cadre of highly qualified professional SMA's, demands that we transcend traditional mind set patterns.

It is not enough to simply change the rules. A replacement set of working guidelines must be described that satisfies all concerned participants.

The members of the CSMAD organization are often challenged to provide a definition of what is an architect and how is an architect different from a systems engineer or a structural engineer. Even though the challenge is often friendly, the message is clear: "perception and understanding are not easily changed." Confusion is furthered with the popular usage of the word "architecture" in many non-technical journals and even some technical articles, when in fact an "engineering design" is often what is meant.

Scope of this Discussion:

This paper attempts to set forth a list of essential architecting products, services, and deliverables that often go overlooked in many development processes. This paper does not attempt to cover all of the aspects of the space mission architecting process.

A clear definition of a SMA's role can be stated in terms of those essential architecting products, services, and deliverables that the SMA is expected to provide and the diversity of

organizations that the SMA must satisfy. A refinement of that statement could then be obtained by examining the skills, tools, and techniques that the SMA uses to meet these mission needs.

Because the very concept of space mission is so all-inclusive, this paper does not attempt to define the term. A space mission might consist of a single space craft, instrument package, orbit, and operations concept. It might consist of a cluster of diverse or similar spacecraft with a similar goal, for examining a moon of Jupiter. It might consist of a scattered array of identical spacecraft, for example searching for long wave fluctuations. The list of possibilities could be longer than the space allowed for proceedings of the conference.

Although the nature of the missions and hence the deliverables vary, the essential architecting products, services, and deliverables can be easily recognized and understood. The community of experts who identify with the role of providing these things define themselves as Space Mission Architects. This approach does, admittedly, sidestep the more common attempt of non-architecting professional people trying to define an abstract architect.

Only NASA and JPL methods and terminology are cited. It is expected that the concepts should be recognized by a wider audience. Within NASA, there are various funding organizations with different science and technology goals. For brevity, they are all designated, herein, as "the customer."

The methods and skills needed to provide the architecting are best presented in references [Rechtin & Mair, 1997] [Rechtin, 1991] and in some of the other papers given here today. Architecting insights to the problems of management are found in reference [Augustine].

Define the Architecting Essentials:

The SMA is responsible for the articulation of the mission's purpose. The SMA is responsible for maintaining the integrity of the mission's purpose.

The SMA is responsible for maintaining an approach that views the mission as a whole. There are a large number of political judgments that go into deciding what science is needed and what mission and what time. There are numerous value judgements for what the mission is expected to return in terms of science data. There are multitudinous design decisions as to what is feasible. The SMA must identify and concentrate on those few critical details and interfaces that are imperative. In this respect, the SMA maintains the relationship between the customer, the scientists, the builders, and the operators. This effort can last, to varying levels, for the duration of the entire mission.

The SMA also oversees the development of the high level specifications.

These are what:

1) the customer needs to understand the scientific and political impact of the mission,

2) the system engineer needs to in order to begin designing,

3) the scientist needs to begin understanding the ramifications of the first draft designs, and

4) the manager needs to understand the scope of the commitments.

Several iterations are needed to even begin the process. In NASA jargon, the process leads to a product that is called, "the Step 1 Proposal." If

approval is received to proceed to Step 2, another iterative process begins and, system engineers turn these high level specifications into detailed specifications and sub-system specialists work from those documents.

The SMA is responsible for the modeling of the mission to predict and analyze the performance, costs, development schedules, operations scenarios, and risks. Modeling is used to identify and solve problems from the beginning conceptualization to the final data return. It is also used to convey the message of the abstractions to the customer, scientists, designer, builder, tester, operator, and general public.

The SMA is responsible for a plan that can be implemented as a "zero defects design" with acceptance tests that are both complete and passable.

The SMA is responsible for the formal certification to the customer, the scientists, and the user that the system, as built, meets the mission acceptance and the builder is paid.

The SMA is responsible for providing the insight to structure the mission descriptions to increase the understanding and decrease the complexity.

Define the constraints:

Much of the conceptual portion of the architecting takes place during the proposal stage of the mission, when the mission has only been funded at a low level or is just an inspired dream of a few people.

Success of the mission is decided by the customer and/or by the public. A mission is perceived as successful only if it meets a useful

purpose at an affordable cost and within an acceptable period. None of these concepts can be held in one's hands or measured. These are not scientific or engineering or management decisions.

Essential Architecting Products:

Some of the items on the following list may seem mundane and someone other than the SMA could do many of them. It is the reapportionment of responsibilities that is noteworthy.

In the earliest stage of the space mission, the SMA provides, or sees to the provision of the following products:

1) Authorization for the preparation of the mission proposal including an appropriate description of the problem ("Don't assume that the original statement of the problem is necessarily the best, or even the right one" [Rechtin and Maier, p.26]);

2) Plans for the descriptions of requirements, cost, and schedules for negotiations leading to mission preparation;

3) Documents describing the perceptions of need for the mission, the requirements in terms of performance, cost, schedule, and risk of the mission;

4) Documents describing the facts of the mission including technology availability, measurements and calibration, and known and expected science gains;

5) Documents describing the acquisition of major items and services, for example launch vehicle, spacecraft, instrument package, data link and data processing, agreements with other organizations for work and/or products;

6) Formal cost estimates for each major element of the mission;

7) Documents describing JPL institutional commitment and backing;

8) Models of the mission from launch to encounter including data taking campaigns and operations;

9) Fallback position papers with key decision points identified and cost or schedule or risk trades.

10) Documents describing the results of negotiations with the customer including perceived strengths and weaknesses in plans;

11) Insights and inspirations to the customer as to the perceived value, to the scientists as to the perceived technical capabilities, to the builders as to the perceived challenge, and to the managers as to the perceived reasons for doing the mission.

As the mission progresses:

12) Plans with built in options that can be maintained for as long as possible;

13) Partitioning of the mission into independent elements with clean interfaces leading to the systems engineer's understanding of the mission priorities and then to the System Requirements Document;

14) Preliminary statements of the test procedures with pass and fail universal agreement of the pass-fail criteria (Certification);

15) Memos and other persuasions suggesting methods for simplification ("Simplify, Simplify, Simplify" [Rechtin and Mair, p. 26]);

16) Customer, scientist, engineer, and manager meeting of the mind as to goals, objectives, methods, and options;

17) Ongoing assessment, prioritization, and rearchitecting.

Conclusions:

It is the author's intent that a development of a list of SMA essential product, services, and deliverables will help delineate the role of the SMA. Many people will respond with items that might have been, or should have been, omitted from the list. It is expected that this report will encourage discussion. Clearly, the final vote is not in yet.

The definition of the list does not provide many clues as to how the SMA goes about in providing the itemized elements. No new surprises have appeared on the list. The value added by the list is the reapportionment of responsibilities. Ready-made and custom-built tools have been and will continue to become available to assist the SMA. Other papers presented here today will expand on those details.

Great strides are already underway to provide a set of tools that offer the SMA a unified environment of modeling, costing, managing, and explaining what goes into a space mission architecture.

The scope of the future challenges can be seen in a few retrospect examples:

Commercial widebody jets have wingspans longer than Wilber Wright's first flight. The first manned flight to the moon started with a rocket

more than twice as high as the altitude attained by Robert Goddard. That same rocket was about the size of a lightning rod attached to the Space Shuttle launch pad. Similar comparisons in terms of complexity, or in terms of number of moving parts, or in terms of interfaces, rather than in terms of size would be at least as amazing.

A single unplanned picture of Earth rising from the moon has changed, forever, the way mankind thinks of itself.

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